TARGET GENERATION FACILITY

TO

FLIGHT SIMULATOR
INTERFACE CONTROL DOCUMENT

(FINAL)

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This updated version of the Target Generation Facility to Flight Simulator Interface Control Document has been revised from the original document that SIR/AS& T TGF and Documentation personnel researched, wrote and produced on August 24, 1992.

NOTE: Comments and updates to this document should be submitted to ACT-510. See Appendix F, Update Form for exact procedure.

LEVEL DATE COMMENTS

- August 24, 1992 New Document
- October 20, 1993 Redesigned data formats.
- February 14, 1994 Added Pressure Altitude field to site data.
- February 16, 1994 Added two flight simulators
- March 11, 1994 Added climb/descend rate to site data. Will allow either < CR> or < LF> as terminated for site data.
- May 2, 1994 Changed sim time to be GMT at site.
- May 15, 1995 1) Changes to Aircraft Update Message (AUM), (Table 4-2) 2) Misc. corrections and updates to the present

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1. INTRODUCTION

The Target Generation Facility (TGF) was developed primarily to perform Operational Test and Evaluation (OT& E) for all phases of the Advanced Automation System (AAS). Additionally, TGF supports the testing of Air Traffic Control (ATC) systems. This testing frequently necessitates interfacing with flight simulators.

1.1 PURPOSE

The TGF to Flight Simulator Interface Control Document (ICD) defines the interface between the Target Generation Facility and flight simulators. This ICD describes the requirements of the communication interface between these systems. New simulators should conform with the data interface standard which is described in Section 4.

1.2 ORGANIZATION

The TGF at the Federal Aviation Administration Technical Center (FAA Technical Center) is managed by theSystem Simulation Support Branch, ACT-510, of the Aviation Simulation and Human Factors Division, ACT-500. Responsibility for the flight simulators rests with the individual sites.

2. FLIGHT SIMULATOR OVERVIEW

The laboratory configuration for supporting the flight simulators, which is shown in Figure 2-1, Flight Simulator Laboratory Configuration, consists primarily of the flight simulators, the Target Generation Facility (TGF) and the Air Traffic Control (ATC) laboratories. The following paragraphs describe the operational flow of this laboratory configuration along with other major interfaces. Initial communication with the flight simulators is established utilizing a SUN workstation. The flight simulators, listed in Appendix C, provide the aircraft data and voice communication to the ATC laboratories. The aircraft data is reformatted by the communication concentrator within the TGF. The TGF then provides the surveillance target data at the required message output rates (e.g. 2.4 seconds, 1 second) and formats necessary to accurately simulate the radar system. The messages output from TGF are sent to the appropriate controller displays in the ATC laboratory. In a typical use of a flight simulator, a scenario is executed using both flight simulators and targets generated by the TGF. The flight simulators are flown by actual pilots whereas the TGF aircraft are "flown" by the Simulation Pilot Operators (SPOs) in the TGF laboratory. During the simulation, both the Simulation Pilot Operators and actual pilots respond to commands issued from the air traffic controllers under normal and "blunder" situations. Analysis is primarily focused on the reaction times and responses between the actual pilots and ATCs as well as the performance of the flight simulator aircraft. The remainder of this document will focus on the hardware and software interface from the TGF to the Flight Simulators.

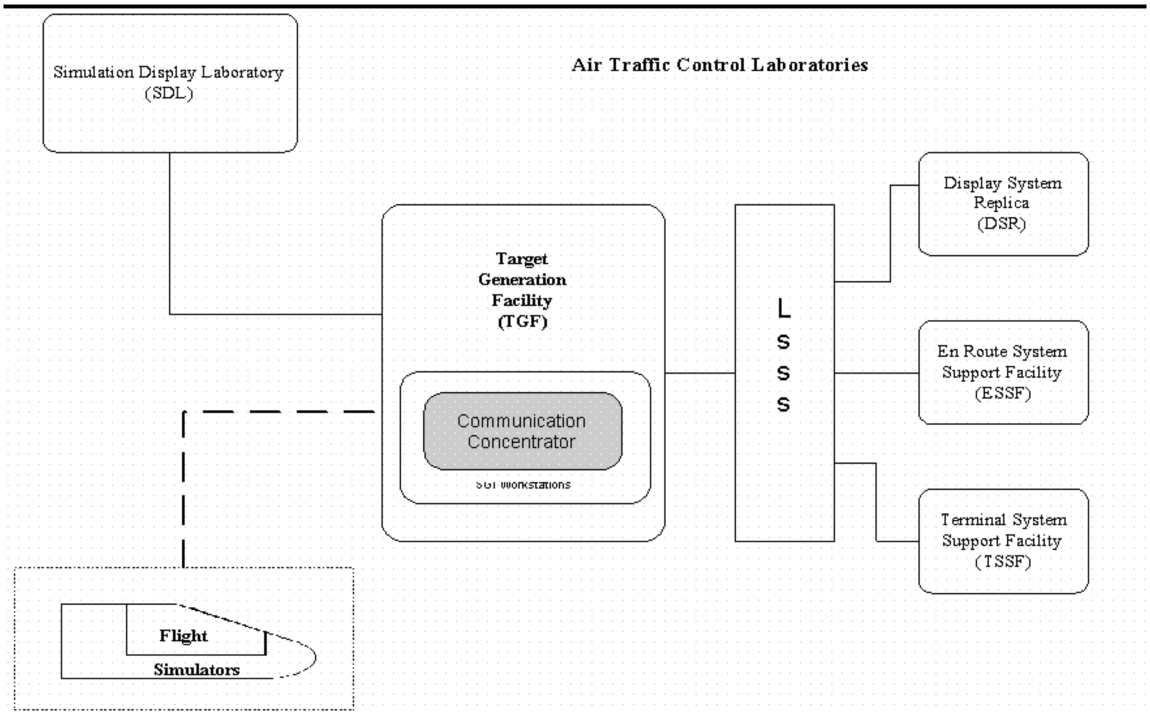


Figure 2-1 Flight Simulator Laboratory Configuration

3. HARDWARE

The following paragraphs describe the TGF hardware including the communication concentrator, the flight simulator hardware and the communication channel.

3.1 TARGET GENERATION FACILITY

The TGF hardware has been allocated into three subsystems as shown in Figure 3-1, TGF Subsystems. These subsystems are Simulation Pilot, Target Generation, and Development and Support.

3.1.1 Simulation Pilot Subsystem

The Simulation Pilot Subsystem consists of both the Simulation Pilot Workstations (SPWs) and the Exercise Control Workstations (ECWs). Each workstation consists of an 80386-based personal computer running under MS-DOS. Pairs of SPWs are mounted inside a customized table which contains a Denro communication system that provides an interface with Air Traffic Controllers. The Simulation Pilot Operators use the SPWs to "fly" the simulated aircraft and command them in accordance with air traffic controller instructions. The Exercise Control Operators (ECOs) use the ECWs to control the execution of the exercise.

3.1.2 Target Generation Subsystem

The Target Generation Subsystem consists of both a Target Generation Chassis and an External Interface Chassis. Each chassis is based upon a VME architecture employing 68030-based processor boards. This subsystem runs under a real time operating system, VxWorks, and executes application programs written in the C language.

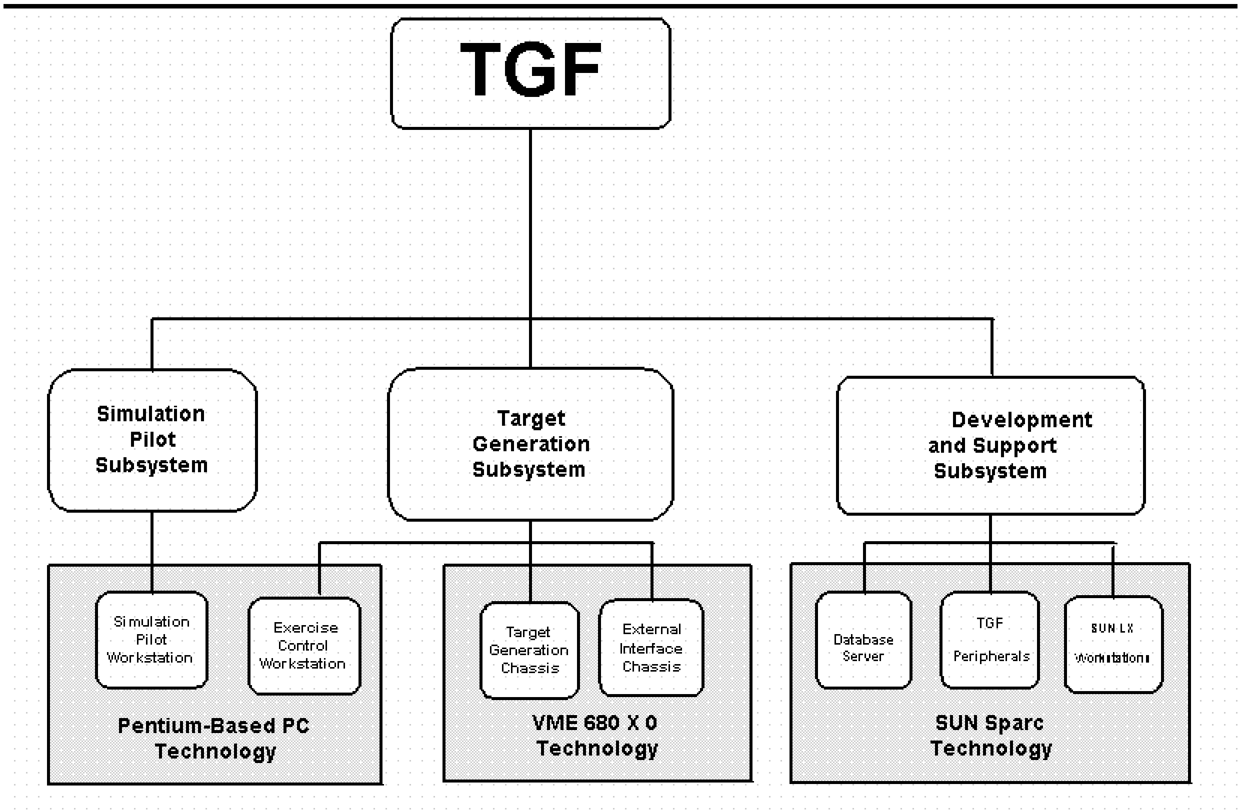
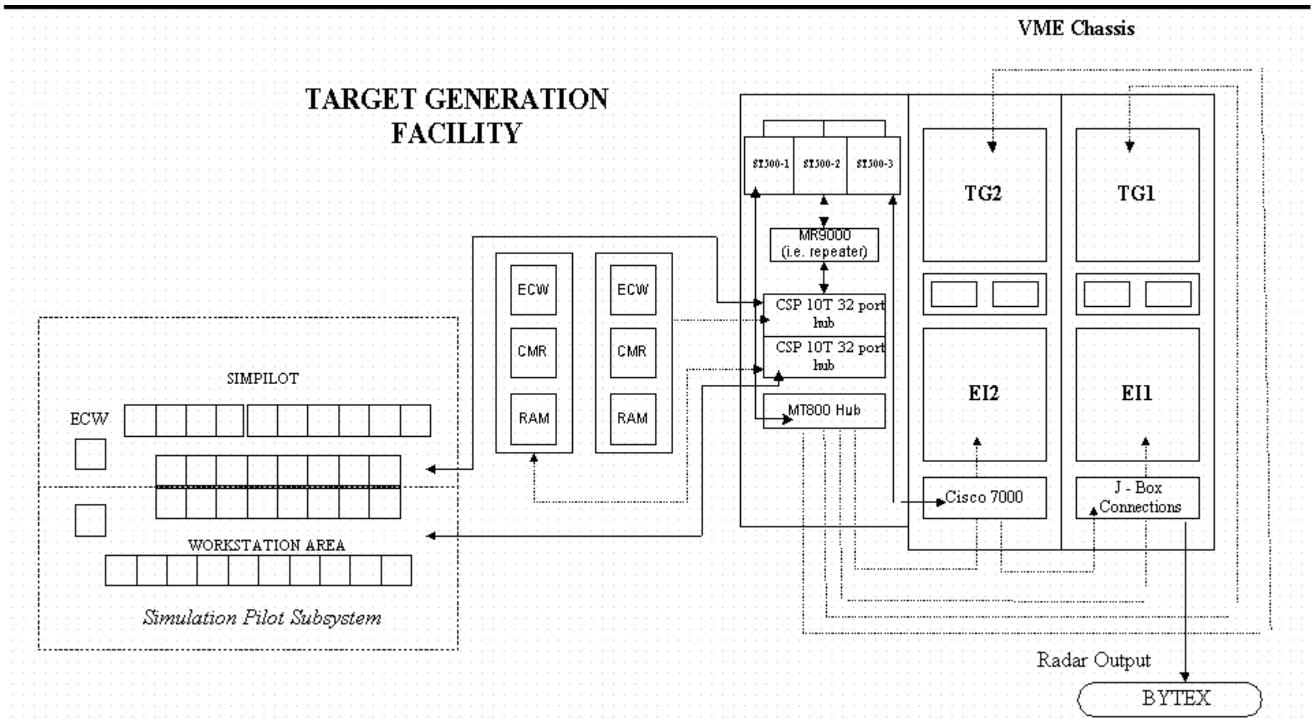


Figure 3-1 TGF Subsystems

The Target Generation Subsystem performs all modeling within the TGF and correlates dynamic data such as aircraft state vectors, radar performance, weather vectors and states, with known flight plan and adaptation data. In addition, this subsystem is responsible for creating the exact form and content of the digitized radar messages sent to the ATC system under test.

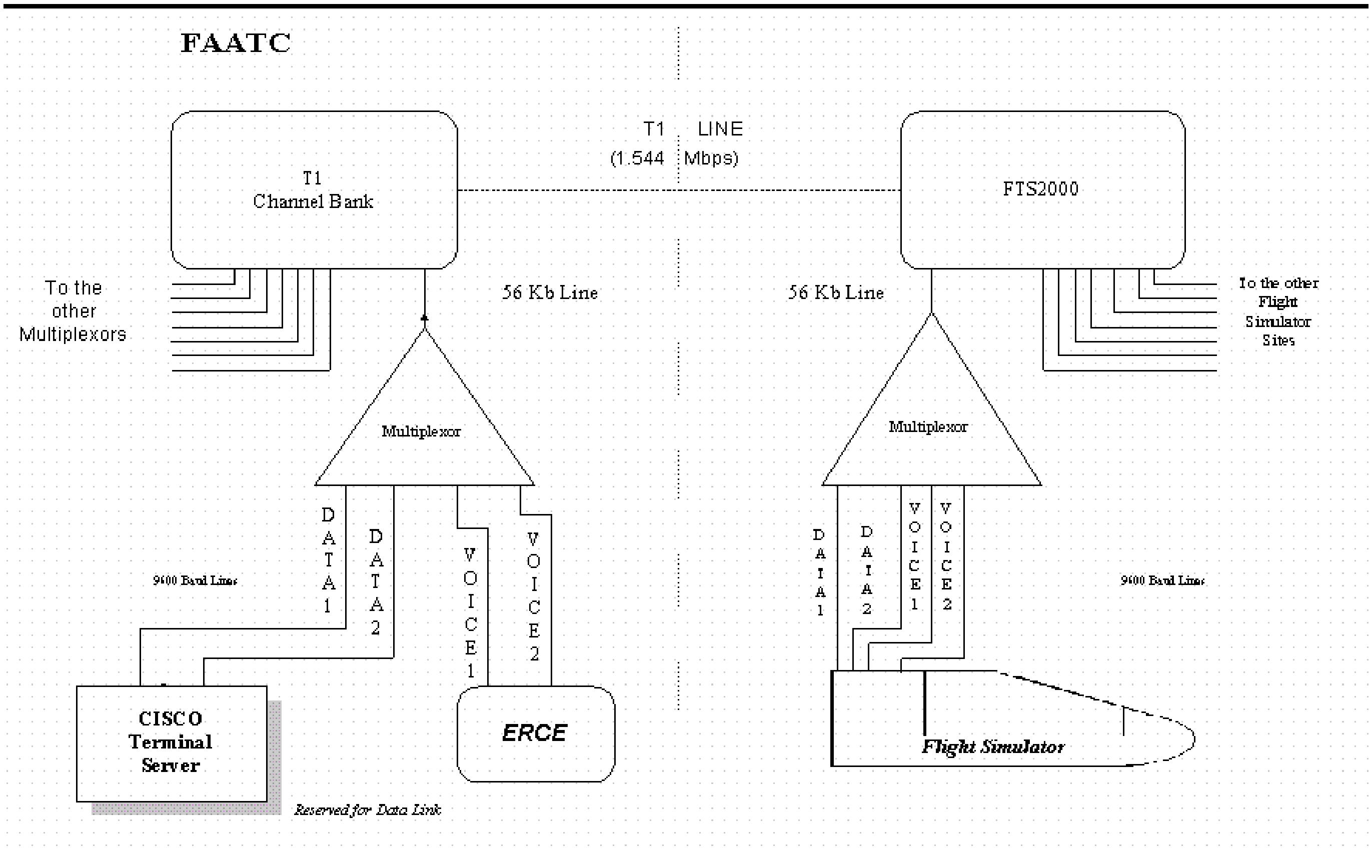
3.1.3 Development and Support Subsystem

The Development and Support Subsystem is based on a SUN architecture that employs a SUN 3/470 as a file server, a set of peripherals, and SUN 3/80 diskless computers as the Development and Support Workstations (DSWs). The Development and Support subsystem uses SunOS UNIX as the operating system. The Development and Support Subsystem provides the basic pre-exercise scenario preparation and validation capabilities for the Scenario Development Analyst (SDA), the post-exercise data reduction and analysis capabilities for the Data Reduction Analyst (DRA), and the resources allocation and monitoring capabilities for the System Monitor Operator (SMO). In addition, this subsystem provides the capabilities necessary to maintain and/or enhance the TGF software. A full range of software development tools, which permit access to the source and object files, is provided via this subsystem. Connectivity between the SUN 3/80s is provided by a Thick-Net Ethernet LAN, while a Thin-Net Ethernet LAN provides communications to the other two TGF subsystems. The TGF Configuration, Figure 3-2, illustrates the interconnectivity of the three subsystems. In order to interface with the flight simulators, the Development and Support Subsystem has been upgraded to include a communication concentrator which consists of a SUN SPARC workstation plus the software necessary to reformat the flight simulator data prior to being processed by the target generator.



3.2 FLIGHT SIMULATOR HARDWARE

The flight simulator hardware consists of a unique flight simulator for a particular aircraft. The types and locations of the current flight simulators interfacing with TGF are listed in Appendix C.



3.3 COMMUNICATION CHANNEL

The communication channel consists of communication equipment, a terminal server, and a router.

3.3.1 Communication Equipment

As illustrated in Figure 3-3,the communication equipment consists of the T1 channel bank, the FTS2000 Digital Access Cross-Connect Switch (DACS), and a set of multiplexors. Each flight simulator has two voice lines and two data lines all of which operate at 9600 bps. These four lines are fed to a multiplexor that combines all voice and data communication into a single 56 Kb dedicated line. Each 56 Kb line, one per flight simulator, is then fed to an FTS2000 DACS. Here, the DACS combines all of the 56 Kb lines into a single T1 (1.544 Mbps) line to the FAA Technical Center. At the FAA Technical Center, the T1 line enters a T1 channel bank which separates the communication for each flight simulator back into 56 Kb lines, through a multiplexor (decoder), and back to two voice and two data lines at 9600 bps. The two voice lines go to the ERCE which will route the signal to the appropriate laboratory for the air traffic controllers. One data line is routed to the CISCO terminal server and the other data line is reserved for future datalink.

3.3.2 Terminal Server

The CISCO terminal server is connected to TGF via Ethernet and utilizes eight asynchronous ports for communication with the flight simulators. The Flight Simulator Configuration, Figure 3-4,illustrates the connectivity of the terminal server, the communication equipment and the current flight simulators interfacing with TGF.

3.3.3 Router

The router networks the TGF with the flight simulators using standard Ethernet cabling and operates with the Transmission Control Program/Internet Protocol (TCP/IP) standard. The TGF to Flight Simulator Network Diagram, Figure 3-5,presents a graphic illustration of the network connectivity between the flight simulators and the TGF. The format of the flight simulator data and additional software issues are presented in the following section.

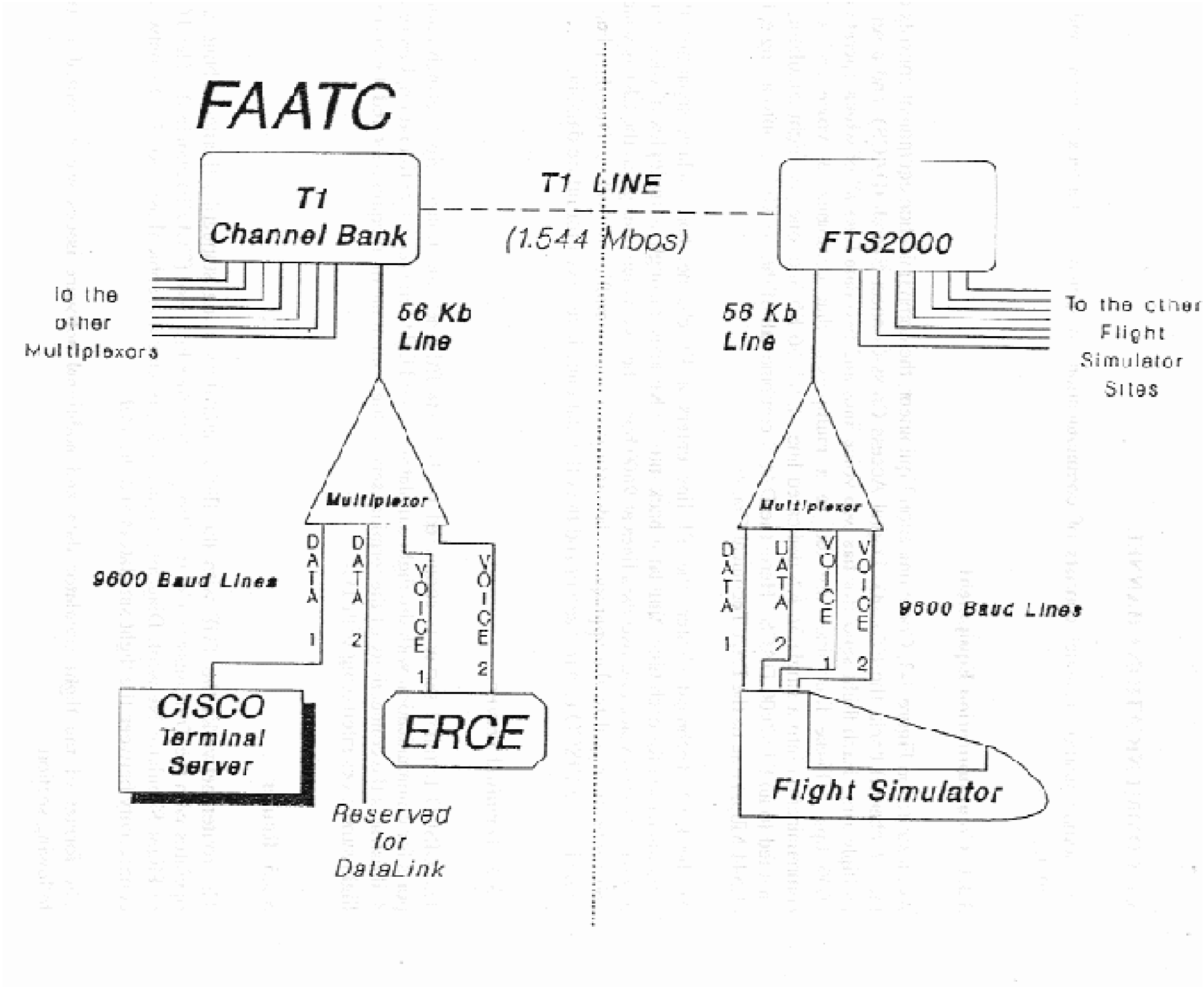


Figure 3-3 Communication Equipment

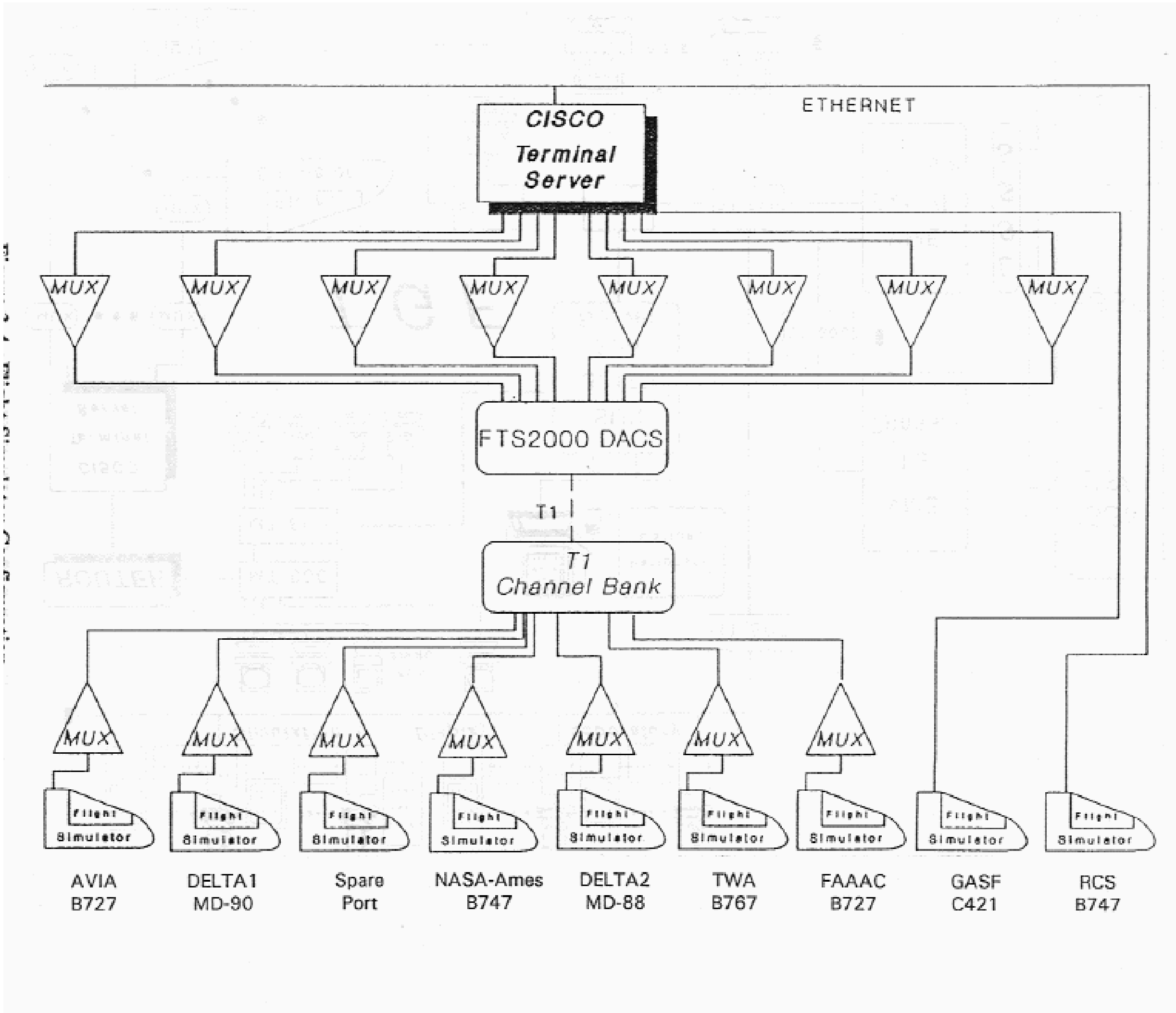


Figure 3-4 Flight Simulator Configuration

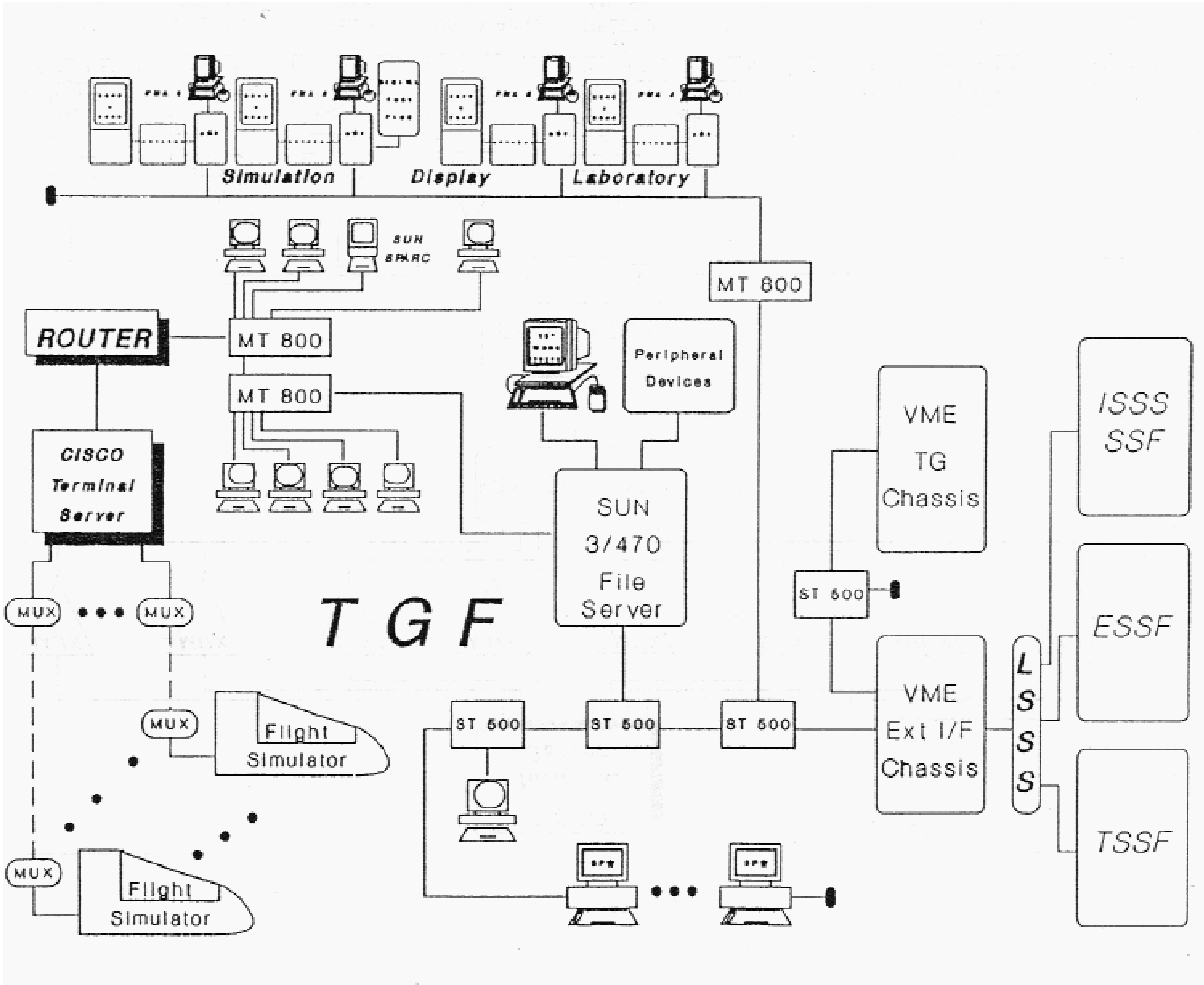


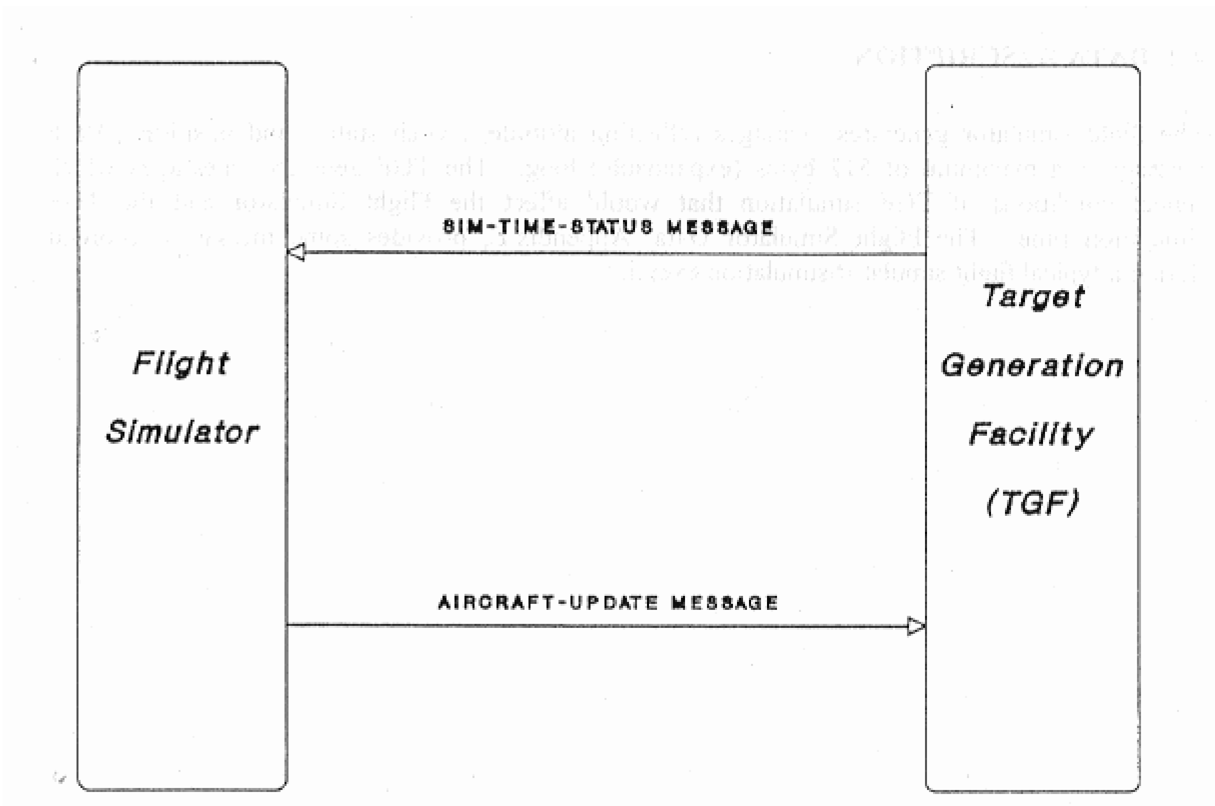
Figure 3-5 TGF to Flight Simulator Network

4. DATA INTERFACE

This section describes the data interface standard between the TGF and the flight simulators.

4.1 MESSAGE FLOW

>The message flow between the TGF and the flight simulators is shown in Figure 4-1, Message Flow Diagram.



4.2 DATA DESCRIPTION

The flight simulator generates messages reflecting altitude, switch status, and position. Each message is a maximum of 512 bytes (expandable) long. The TGF generates messages which reflect conditions of TGF simulation that would affect the Flight Simulator and the TGF simulation time. The Flight Simulator Data, Appendix E, provides some messages recorded during a typical flight simulator simulation exercise.

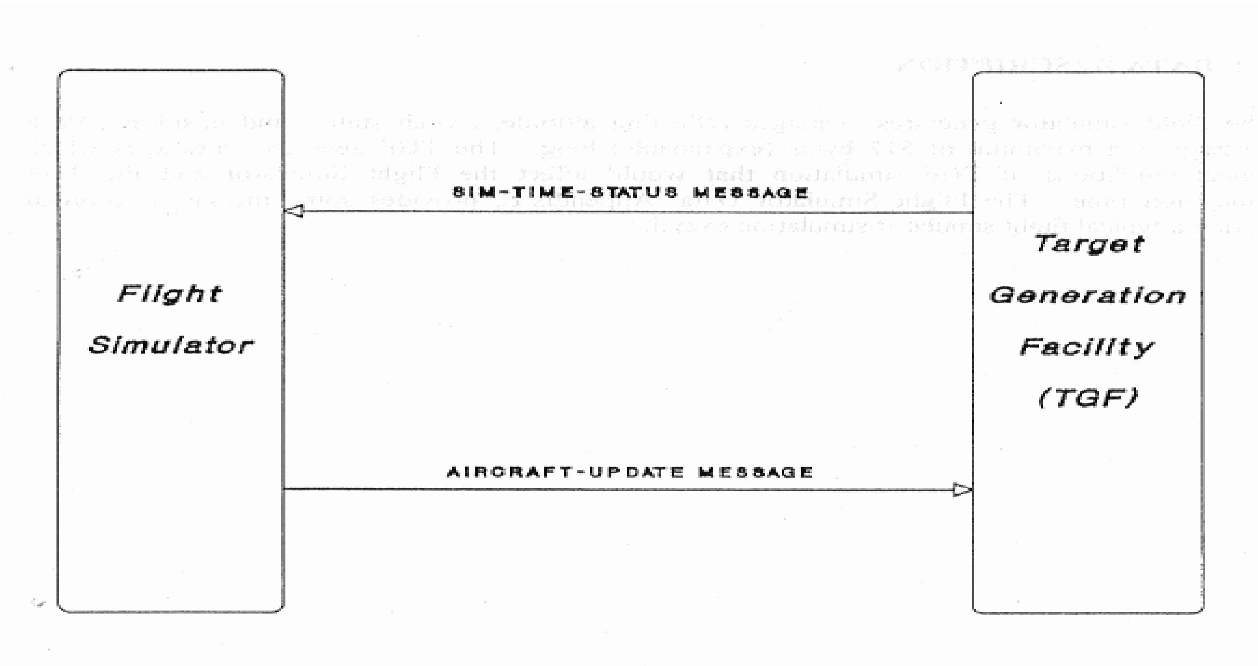


Figure 4-1 Message Flow Diagram

4.3 TARGET GENERATION TO FLIGHT SIMULATOR MESSAGE

4.3.1 Sim-Time-Status Message

The Sim-Time-Status Message notifies the Flight Simulator of the simulation time each second. This message is used to achieve final coordination between the Flight Simulator and Air Traffic Control. Table 4-1 presents the format of the Sim-Time-Status Message.

Table 4-1 SIM-TIME STATUS MESSAGE

FIELD NO.	FIELD NAME	LENGTH (Byte)	FORMAT	VALUE
1	**START**	**3**	**'%NN'**	**'%09'**
	FIELD SEPARATOR	**1**	**' '**	
2	**SIM-TIME**	**8**	**'HH:MM:SS'**	
	FIELD SEPARATOR	**1**	**' '**	
3	**SIM-STATUS**	**4**	**'AAAA'**	**'TERM', ' RUN', or 'FREZ'**
	FIELD SEPARATOR	**1**	**' '**	
4	**ACID**	**7**	**'AAAAAAA'**	
	FIELD SEPARATOR	**1**	**' '**	
5	**BEACON**	**4**	**'NNNN'**	**OCTAL**
	FIELD SEPARATOR	**1**	**' '**	
6	**FREQUENCY**	**7**	**'NNN.NNN'**	
7	**END**	**2**	**'0D0A'**	**ASCII CR/LF**

4.3.1.1 Data Field 1 - Start of Message (START)

The Start of Message consists of a 3-byte ASCII character field containing a '%' followed by a zero and a nine for unique message identification.

4.3.1.2 Field Separator

A 1-byte ASCII space character is provided between each field to assist in the readability of this data on the cockpit simulator site terminals.

4.3.1.3 Data Field 2 - Simulation Time (SIM-TIME)

The Simulation Time Identification of the TGF System consists of an 8-byte ASCII character field representing the current simulation time in hours, minutes, and seconds. The hours field is based on the 00- 24 24-hour format ("military time").

```
Format: 'HH:MM:SS'
Example: '00:12:35'
```

This field is used to synchronize the time among all of the sites.

4.3.1.4 Data Field 3 - Simulation Status (SIM-STATUS)

The Status of the TGF experiment indicates the current state of the simulation. It consists of a 4-byte ASCII character field with the values 'TERM', ' RUN', or 'FREZ'.

4.3.1.5 Data Field 4 - Aircraft Identification (ACID)

The Aircraft Identification consists of a left-justified and blank-filled aircraft ID in a 7-byte ASCII character field. This field is provided as information for the simulator sites only and may be blank when data is not available.

```
Format: 'AAAAAAA'
Example: 'DAL58  '
```

4.3.1.6 Data Field 5 - Beacon Code (BEACON)

The Beacon Code consists of a right-justified and zero-filled octal integer beacon code in a 4-byte ASCII character field. This is also called the Transponder Code. This field is provided as information for the simulator sites only and may be blank when data is not available.

```
Format: 'NNNN'
Example: '0473'
```

4.3.1.7 Data Field 6 - Frequency (FRQUENCY)

The Frequency consists of a 7-byte ASCII character field representing the communication frequency. This field is provided as information for the simulator sites only and may be blank when data is not available.

```
Format: 'NNN.NNN'
Example: '135.75 '
```

4.3.1.8 Data Field 7 - End of Message (END)

The End of Message, which must be present to indicate the end of each message, consists of two ASCII bytes with values '0D0A' expressed in hexadecimal notation. This is the ASCII carriage return/line feed combination (CR/LF).

4.4 FLIGHT SIMULATOR TO TGF

4.4.1 Aircraft-Update Message

The Aircraft-Update Message sends new aircraft positioning information to the TGF for processing at the rate of at least once per second. The preferred update rate is once every half-second. The TGF displays the new Flight Simulator position.

Table 4-2 presents the format of the Aircraft Update Message.

Table 4-2 AIRCRAFT UPDATE MESSAGE

FIELD NO.	FIELD NAME	LENGTH (Byte)	FORMAT	VALUE
1	**START**	**3**	**'%NN'**	**'%10'**
2	**ACID**	**7**	**'AAAAAAA'**	
3	**BEACON**	**4**	**'NNNN'**	**OCTAL**
4	**LATITUDE**	**10**	**'±NN.NNNNNN'**	**DEGREES**
5	**LONGITUDE**	**11**	**'±NNN.NNNNNN'**	**DEGREES**
6	**ALTITUDE**	**6**	**'NNNNNN'**	**FEET**
7	**ALTITUDE (PRESSURE)**	**6**	**'NNNNNN'**	**FEET**
8	**CLIMB-DESC-RATE**	**5**	**'±NNNN'**	**FT/SEC**
9	**STATUS**	**1**	**'I', 'O', 'T'**	**'IN', 'OUT' or 'TERM'**
10	**HEADING**	**6**	**'NNN.NN'**	**DEGREES**
11	**IND-SPEED**	**6**	**'NNNN.N'**	**NM/HR**
12	**TRUE-SPEED**	**6**	**'NNNN.N'**	**NM/HR**
13	**IDENT**	**1**	**'I'**	**'I' or ' '**
14	**FREQUENCY**	**7**	**'NNN.NNN'**	
15	**EPR**	**4**	**'N.NN'**	
16	**SIM-TIME**	**12**	**'HH:MM:SS.SSS'**	
17	**MESSAGE COUNTER**	**6**	**'NNNNNN'**	**INTEGER**
18	**END**	**1**	**'0D' or '0A'**	**ASCII CR/LF**

4.4.1.1 Data Field 1 - Start of Message (START)

The Start of Message consists of a 3-byte ASCII character field containing '%', followed by a one and a zero for unique message identification.

4.4.1.2 Data Field 2 - Aircraft Identification (ACID)

The Aircraft Identification consists of a left-justified and blank filled aircraft ID in a 7-byte ASCII character field.

```
Format: 'AAAAAAA'
Example: 'DAL58  '
```

This field is optional and provided for readability and debugging.

4.4.1.3 Data Field 3 - Beacon Code (BEACON)

The Beacon Code Identification consists of a right-justified and zero-filled octal integer beacon code in a 4-byte ASCII character field. This is also called the Transponder Code.

```
Format: 'NNNN'
Example: '0473'
```

Refer to Appendix D for usage of this field.

4.4.1.4 Data Field 4 - Latitude (LATITUDE)

The Latitude consists of a 10-byte decimal ASCII character field containing a fixed-point, blank-filled real value representing degrees, preceded by either '+', '-', or ' ', where '+' or ' ' indicates Northern Hemisphere and '-' indicates Southern Hemisphere.

```
Format: '±NN.NNNNNN'
Example: '+38.296734'
```

4.4.1.5 Data Field 5 - Longitude (LONGITUDE)

The Longitude consists of a 11-byte decimal ASCII character field containing a fixed-point, blank-filled real value representing degrees preceded by either '+', '-', or ' ', where '+' or ' ' indicates Western Hemisphere and '-' indicates Eastern Hemisphere.

```
Format: '±NNN.NNNNNN'
Example: '+123.567894'
```

4.4.1.6 Data Field 6 - Altitude (ALTITUDE)

The Altitude consists of a 6-byte ASCII character field containing a blank-filled integer value representing feet. This field contains true (MSL) altitude.

```
Format: 'NNNNNN'
Example: ' 10000'
```

4.4.1.7 Data Field 7 - Altitude (PRESSURE)

The Altitude consists of a 6-byte ASCII character field containing a blank-filled integer value representing feet. This field contains pressure altitude.

```
Format: 'NNNNNN'
Example: ' 10000'
```

4.4.1.8 Data Field 8 - Climb/Descent Rate (CLIMB-DESC-RATE)

The Climb/Descent Rate consists of an 5 byte ASCII character field containing a blank filled real value representing feet per second. The first byte can be either a '+', '-', or ' ', where '+' and ' ' are positive. This is shown in the following format and example:

```
Format: '±NNNN'
Example: ' 123'
```

Note: Positive values are climbs, negative ones are descents.

4.4.1.9 Data Field 9 - Status (STATUS)

The status field consists of a 1-byte ASCII character field representing cockpit status. It will determine if a simulator site has control of an aircraft. 'O' for out of the simulation, 'I' for in the simulation, or 'T' to terminate last controlled aircraft. Refer to Appendix D for further explanation of this field.

4.4.1.10 Data Field 10 - Heading (HEADING)

The Heading consists of a 6-byte ASCII character field containing a fixed-point, blank-filled real value representing magnetic degrees.

```
Format: 'NNN.NN'
Example: '123.56'
```

4.4.1.11 Data Field 11 - Indicated Air Speed (IND-SPEED)

The Indicated Air Speed consists of an 6-byte ASCII character field containing a fixed-point, blank-filled real value representing knots (nautical miles per hour). This is the speed displayed in the Flight Simulator, not the speed as observed from the ground.

```
Format: 'NNNN.N'
Example: '1234.6'
```

4.4.1.12 Data Field 12 - True Air Speed (TRUE-SPEED)

The True Air Speed consists of an 6-byte ASCII character field containing a fixed-point, blank-filled real value representing knots (nautical miles per hour).

```
Format: 'NNNN.N'
Example: ' 123.5'
```

4.4.1.13 Data Field 13 - Transponder

The transponder field consists of a 1-byte ASCII character field representing the transponder status of the aircraft. The field will be set to "I" when the pilot has pressed the IDENT button in the cockpit. Ident implies that the transponder is transmitting. This field will be set to "S" when the transponder is in standby mode and not transmitting. Otherwise, this field is blank to indicate the transponder is on and transmitting.

4.4.1.14 Data Field 14 - Frequency (FREQUENCY)

The Frequency consists of a 7-byte ASCII character field representing the communication frequency. The frequency must be a valid simulation frequency or TGF will ignore it and default to zero (for no communications).

```
Format: 'NNN.NNN'
Example: '135.75 '
```

4.4.1.15 Data Field 15 - Engine Pressure Ratio (EPR)

This field consists of a 4-byte ASCII character field containing a fixed-point, zero-filled real value representing the current EPR from the cockpit simulator. This will be used in data analysis. The EPR should be obtained from the center, inboard engine, or multi-engine aircraft.

```
Format: 'N.NN'
Example: '0.80'
```

4.4.1.16 Data Field 16 - Simulation Time (SIM-TIME)

The Simulation Time consists of an 12-byte ASCII character field representing the current Greenwich Meridian Time (GMT) in hours, minutes, and seconds.

```
Format: 'HH:MM:SS.SSS'
Example: '16:12:35.913'
```

This field is provided for error tracking.

4.4.1.17 Data Field 17 - Message Counter

The Message Counter consists of a 6-byte ASCII character field containing a zero- or blank-filled integer value that will start at zero at the start of a simulation and increment for each message sent. This field will be used for recognizing lost messages.

```
Format: 'NNNNNN'
Example: ' 2810'
```

4.4.1.18 Data Field 18 - End of Message (END)

The End of Message, which must be present to indicate the end of each message, consists of a 1-byte ASCII character field with a value of either hexadecimal '0D' (ASCII carriage return < CR>) or hexadecimal '0A' (ASCII line feed < LF>).

5. TCAS filter for TGF

5.1 INTRODUCTION.

This document contains specifications and data formats to enable a function to be added to the Technical Center's Target Generator Facility (TGF) to permit traffic awareness in end-to-end airspace simulations. The Data Link program at the Center has a requirement to display proximate traffic in an airspace simulation to flight crews operating flight simulators networked to the TGF. The display of proximate traffic will be by means of aircraft images in the out-of-the-window scene of the simulator, and by means of threat symbols on the simulator's TCAS.

Traffic in the simulation may consist of simulator operator driven targets, or other flight simulators.

The Airborne Data Link Program at the Center is concerned with human factors issues relating to the time spent by flight crews interacting with Data Link clearances from air traffic control (ATC). There is an industry concern that Data Link communications will reduce the awareness of the airspace conditions around the aircraft, and will distract flight crews away from visually scanning the airspace outside the aircraft. End to end simulations have not been heretofore able to address these issues except in limited case studies using scripted scenarios. In the end-to-end simulations performed at the Center, the level of fidelity in the ATC simulation implies stochastic traffic interactions and requires that traffic information is made available on the fight deck.

5.2 CONSTRAINTS.

Flight Simulators are linked by means of a limited bandwidth network that has only 9.6 kilo-bits per second transmission capability. Therefore, the TGF must filter the larger data set to derive traffic information that is sent to each cockpit. A two step algorithm is proposed in this paper, consisting of a coarse filter followed by a fine filter. This approach is thought to save computing power in the TGF by applying the more computational intensive (fine) filter to a data set which has been reduced by the coarse filter.

Target data must be sent to each simulator site at a rate of not less than once per second. Simulator host computers can interpolate the position of the target aircraft, but require a frequency of update of Hz to minimize the error. Current thinking is that simulator host computers can derive position and attitude of target aircraft from the track data sent to the host. For example, from the rate of change of heading is derived the rate of turn, and hence the required bank angle of the wings of the aircraft image.

The last constraint applied to this function is the number of aircraft tracks that can be sent to each simulator, owing to the limited bandwidth of the network.

5.3 MESSAGE FORMATS.

5.3.1 DATA REQUIREMENTS.

Table 1. shows the parameters required to generate the proper presentation in the flight simulator visual scene and TCAS.

TABLE 1. Aircraft State Parameters Required for Traffic Awareness at Remote Sites

Parameter	Units	Precision	Size
1. Latitude, Longitude	dd.mm.ss	1/10 sec (ARC)	40 bits
2. Aircraft ID	AAA.NNN note 1	N/A	48 bits
3. Time	mm.ss	1/10 sec (Time)	12 bits
4. Altitude	xx00 feet note 2	100 feet	12 bits
5. Heading	ddd	1 degree	12 bits

Note 1. Aircraft ID is expressed as the flight ID, or UAL232.
Note 2. Altitude is expressed in hundreds of feet.

From the data in table 1, target information can be derived as discussed in the following paragraphs.

5.3.1.1 Target Velocity and Track.

Latitude and Longitude as expressed can be smoothed using an alpha-beta integrator at the remote site to produce first order time differences which can be computed as velocity. Furthermore, successive reports will produce a target track and heading. The heading parameter, shown in table one will be used to normalize the position of the aircraft at run startup, and also to correct the apparent heading of the target in wind conditions.

5.3.1.2 Altitude and Altitude Rate.

Successive altitude reports can be used to derive the climb or descent rate of the target aircraft. A potential limitation in this approach is the time lag after a vertical maneuver begins and altitude bin crossings are evident in the data. This lag will be more pronounced at very low maneuver rates. For example, at a 600 feet per minute rate of climb or descent, the first bin crossing will occur after a minimum of 5 seconds and can be lag as much as 10 seconds.

It is believed that this lag will not affect the results of an end-to-end simulation because lower maneuver rates are not perceptible, and are not typical of terminal area maneuvering speeds.

5.3.1.3 Aircraft ID (ACID).

This parameter is used to tell the image generator at the remote site what type of aircraft should be depicted in the window scene. Using table lookup, the aircraft type can be associated with the correct visual image during each run. Furthermore, the ACID is used to associate track data with a particular aircraft.

5.3.1.4 Time.

This parameter is used in all of the tracking algorithms to eliminate the effects of transmission lag over the data network to the remote site. At the epoch target data are extracted by the TGF, the data are time stamped such that the tracking algorithms at the remote site can dither the data to its correct sampling event.

5.3.2 MESSAGE FORMATS.

The format for the target position data message for all targets is shown in Figure 1.

Message ID | No. of Records | Record 1 | Record 2 | Record 3 ...| Record N | Parity

1. Message ID: Unique identifier of the TCAS record.

Length: 16 Bits

2. No. of Records: This is the number of aircraft tracks that are contained within the data block.

Length: 8 Bits

3. Record Format: See Figure 2

4. Parity: This is a Cyclic Redundancy Check character.

Length: 16 bits

Figure 1. Traffic Data Message Format

The format for each aircraft data record is shown in Figure 2.

Sequence No.| Time| Latitude| Longitude| Heading| Altitude| ACID| End of Message

1. Sequence No: This number increments for each record for each aircraft. Note that the sequence applies only to the particular aircraft that this record describes. All sequence numbers increment independently.

Note: This sequence number is required for those simulation studies where aircraft are reintroduced into the scenario without terminating the run. Generally the aircraft ID changes when aircraft are re-introduced and the record would apply to a different aircraft. However, the sequence number prevents ambiguity in the remote site tracker.

Length: 16 Bits

2. Time: This is the time stamp of the event that the target data is derived from the TGF tracker.

Length: 12 Bits

3. Latitude: This is the latitude of the target at the time stamp.

Length: 20 Bits

4. Longitude: This is the longitude of the target at the time stamp.

Length: 20 Bits

5. Heading: This is the current magnetic compass heading of the target at the time stamp. The field is right justified, with zeros in the unused bits.

Length: 12 Bits

6. Altitude: This is the Gilliam (Gray) encoded altitude of the aircraft in hundreds of feet, normalized to mean sea level barometric pressure of 29.92 inches of mercury.

Length: 12 Bits.

7. Aircraft ID: ACID. This is the flight identification of the target, in character format. General aviation aircraft are expressed as N-xxx or W-xxx with zeroes in the leading alpha positions in the field. If there are more than three numbers in the tail number, the excess digits are truncated.

Length: 48 Bits

5.3.3 TRANSMISSION RATE

Data shall be transmitted continuously, but updated once per second. Total message length is 40 bits of overhead plus 140 bits per target aircraft record. At 9600 bits per second, a maximum of 68 aircraft records can be sent every second to each flight simulator.

5.4 FILTERING ALGORITHMS.

5.4.1 DATA REQUIREMENTS.

This ICD suggests a coarse filter to remove the bulk of traffic in the vicinity of the flight simulator. Then a fine filter can be applied to remove all remaining traffic that is of no consequence. The two filters are described in the following sections.

5.4.1.1 Coarse Filter.

All aircraft within a slant range of 15 nautical miles, regardless of relative altitude, should be associated with the flight simulator. This range is selected because at high relative convergence rates knots, the minimum alert time requirement for TCAS is satisfied:

```
        t = 3600*R/Rdot

                where: t=tau, TCAS alert time

                       R=range between aircraft

                       Rdot=closing rate in knots (kts)
```

at true airspeeds of 500 kts per aircraft, the closing rate is 1000kts; the minimum TCAS alert time is 45 seconds. The minimum range gate is therefore t*Rdot/3600=12.5 miles. The condition is satisfied.

5.4.1.2 Fine Filter.

Figure 3 shows a polar plot of the of the filter shape factor as a function of bearing relative to the flight simulator boresight heading. The plot is generated from the COSINE squared function. A cartioid pattern generated from a COSINE function is plotted on the same axis to show the effect of the second order. Note that the filter goes to zero at 90 and 270 degrees, which eliminates all abeam traffic. Since some abeam traffic must be included, such as would be present during parallel approaches, a static offset is added to the filter function. The complete filter is implemented as follows:

```
R=2.5+10*COS(f) A=Alt +/- 5000 feet

where f is the angle relative to a line extending along
the long axis
of the aircraft (also called the boresight angle).
```

Thus any aircraft within R miles of the flight simulator, and within +/- 5000 of the simulator's altitude should be associated with the flight simulator. The pattern shown in figure 3 is affectionately known as the Tylenol pattern and is intended to cure headaches from too much traffic.

5.4.2 IMPLICATIONS OF THE FILTERS

To estimate the effect of the filter, the area enclosed by the offset COSINE squared function must be calculated.

```
 2P
a=      òRdf
 0


   2P
a=ò2.5+10*COS2(f)df     COS2(f)=1/2(1-COS(2f))
 0


=2.5f+10*[1/2(f+0.5*SIN(2f)    evaluated at 0, 2P
       =2.5*P + 10*P
       =39.3 miles2
```

If the airspace is 25 miles in diameter, and includes 120 aircraft (randomly distributed), then the number of aircraft in the filter is calculated as:

```
Area (airspace)= P*12.52
               =491 miles2

n aircraft= 120*39.3/491
         =9.6 aircraft
```

Thus, the effect of the filter is to reduce the number of air by a factor of five over a slant range filter of the same maximum range as the COSINE squared filter.

5.4.3 COMPUTATIONAL SUGGESTIONS.

It is suggested that TGF personnel implement the coarse range filter on a simulator by simulator basis to build a set of targets which may be elligible for transmission to each simulator. Next, the altitude test of the fine filter is suggested, followed by the range test. The range test within the fine filter requires knowlege of the bearing of each target aircraft to the boresight bearing of each flight simulator; this is calculated from lat/lon positions. This bearing is used as the parameter f in the range test.

If the COSINE squared function in inconvenient for computational purposes, the lookup table shown in Table 3 may be used. To use the table, round the bearing to the next lowest 10 degrees and look up the value of the COSINE squared.

APPENDIX A - ACRONYM LIST A

AS Advanced Automation System
ATC Air Traffic Control bps Bit Per Second COTS Commercial-Off-the-Shelf
DACS Digital to Analog Converter System
DRA Data Reduction Analyst
DSW Development and Support Workstation
ECO Exercise Control Operator
ECW Exercise Control Workstation
ERCE Ernie's Radio Control Equipment
ESSF En Route System Support Facility
EXT I/F External Interface
FAA Technical Center Federal Aviation Administration Technical Center
FMA Final Monitor Aids
GASF General Aviation Simulation Facility
GMT Greenwich Mean Time HEX Hexadecimal
ICD Interface Control Document
ISSS Initial Sector Suite System
Kb Kilo Bits
LAN Local Area Network
LSSS Laboratory Signal Switching System
Mbps Mega bits per second
MS-DOS Microsoft-Disk Operating System
MUX MUltipleXor
OT& E Operational Test and Evaluation
SDA Software Development Analyst
SDL Simulation Display Laboratory
SMO System Monitor Operator
SPO Simulation Pilot Operator
SPW Simulation Pilot Workstation
SSF System Support Facility
TCP/IP Transmission Control Protocol/Internet Protocol
TG Target Generation
TGF Target Generation Facility
TSSF Terminal System Support Facility
VME Versabus Module Europe

APPENDIX B - ORGANIZATIONAL RESPONSIBILITY

Aviation Simulation and Human Factors Division ACT-500

John Wiley, Division Manager 609-485-6400

System Simulation Support Branch ACT-510

Adam Greco, Branch Manager 609-485-4405
Dan Warburton (TGF) 609-485-4480
Richard Ozmore (Real-Time) 609-485-5368

APPENDIX C - FLIGHT SIMULATORS

TYPE AGENCY LOCATION

B727-100 AVIA Leasing Costa Mesa, CA

B747-400 NASA-Ames Mountain View, CA

MD-88 Delta Airlines Atlanta, GA

MD-90 Delta Airlines Atlanta, GA

B767 TWA St. Louis, MO

B727-200 FAA Aeronautical Center Oklahoma City, OK

C421 FAA Technical Center Atlantic City International Airport, NJ

B747 (RCS) FAA Technical Center Atlantic City International Airport, NJ

B747-400 United Airlines Denver, CO

APPENDIX D - FLIGHT SIMULATOR

COCKPIT STATES

Cockpit states:

The cockpit simulator sites will have 2 separate fields in the simulator data message to control the state of the target TGF aircraft.

The first field is the "status" field. This can be set to:

> **'O' for out of the simulation,**
>
> **'I' for in the simulation, or**
>
> **'T' to terminate last controlled aircraft.**

The second field for aircraft control is the "beacon" field. This determines which TGF aircraft the simulator site will take control of.

The process flow for a simulator site to take over control of a TGF aircraft is as follows:

The simulator site would start sending aircraft update messages with the status field set to 'O' (for OUT of the sim) and the beacon field would be set to the target aircraft beacon code.

When the time to enter the simulation occurs, the status field would change to 'I' (for IN the simulation).

When the aircraft has landed, or otherwise is to be removed from the simulation, the status field must be changed to 'T' (to TERMINATE the aircraft).

The above describes the process flow for an ideal setup. The following will attempt to cover how any deviations from the ideal will be handled.

1. TGF aircraft is not in the simulation when the simulator site changes the status to 'I'.

The data being sent by the simulator site will be ignored until the time TGF generates the simulated aircraft to take control of. Once TGF starts the desired simulated aircraft, the simulator site will take control within the first few seconds of that aircraft's flight.

2. Simulator site changes status from 'I' to 'O'.

Once a site takes control of a TGF aircraft, it will not be returned to TGF sim-pilot control. Therefore, when the status changes to 'I', the simulator site will take control of that aircraft until the aircraft is terminated. If the status changes back to 'O', the simulator site will still retain control of the aircraft. If the simulator site again changes status back to 'I', TGF will handle the aircraft as if the simulator site had just taken control of the aircraft, including using the cockpit simulator current position information from that time forward.

Note that this status change between 'I' and 'O' can occur any time during the flight, and multiple times during the flight, with the same results each time.

3. Simulator site changes status from 'T' to either 'I' or 'O'.

Once the status of 'T' is received, the aircraft is terminated from the simulation and can not be retrieved. All future status changes for this aircraft will be ignored.

4. Loss of data from a simulator site.

When the loss of data occurs after the site has control of an aircraft, TGF will project the path of the aircraft based on the last valid aircraft position data (i.e., heading, speed, and altitude). When the loss of data is for an extended period, the target will go into coast for most external labs. When data is again received from the simulator site, this data will become the aircraft current position data. Note that this may cause a target "jump" if the loss of data is for a significant time.

5. Beacon code changes when current status is 'I'.

This case will be considered a valid change and the current aircraft under control will start transmitting the new beacon code to the controller displays. Note that if the new beacon code is a duplicate of an active TGF simulated aircraft, the TGF duplicate is unchanged and remains under control of the sim-pilot. Therefore, the current aircraft under simulator site control can still be terminated, the status changed first to 'O', and then the status is changed to 'I' to take control of the TGF simulated aircraft with the same beacon code.

APPENDIX E - SAMPLE DATA

Example Messages from TGF to Cockpit

Sim-time Status Acid Beacon Freq

%09 16:00:01 FREZ ACID001 1234 135.750

%09 16:00:01 FREZ ACID001 1234 135.750

%09 16:00:01 RUN ACID001 1234 135.750

%09 16:00:02 RUN ACID001 1234 135.750

%09 16:00:03 RUN ACID001 1234 135.750

%09 16:00:04 RUN ACID001 1234 135.750

%09 16:00:05 RUN ACID001 1234 135.750

%09 16:00:06 RUN ACID001 1234 135.750

%09 16:00:07 TERM ACID001 1234 135.750

Example Messages from Cockpits to TGF

Acid Beacon Lat Lon Alt Alt S Hdg IAS TAS I Freq EPR Sim-time Msg-cnt %10ACID0011234 31.818593 99.432817 22200 0O149.85 156.5 164.8 135.7500.8016:00:01.014 1

%10ACID0011234 31.818593 99.432817 22200 0O149.85 156.5 164.8 135.7500.8016:00:01.996 2

%10ACID0011234 31.818593 99.432817 22200 0O149.85 156.5 164.8 135.7500.8016:00:02.972 3

%10ACID0011234 31.818593 99.432405 22200 0I149.85 156.5 164.8 135.7500.8016:00:03.948 4

%10ACID0011234 31.818593 99.431779 22200 0I149.85 156.5 164.8 135.7500.8016:00:04.916 5

%10ACID0011234 31.818593 99.431362 22200 0I149.85 156.5 164.8I135.7500.8016:00:05.880 6

%10ACID0011234 31.818593 99.430944 22200 0I149.85 156.5 164.8 135.7500.8016:00:06.873 7

%10ACID0011234 31.818593 99.430533 22200 0I149.85 156.5 164.8 135.7500.8016:00:07.895 8

%10ACID0011234 31.818593 99.429918 22200 0I149.85 156.5 164.8 135.7500.8016:00:08.914 9

%10ACID0011234 31.818593 99.429491 22200 0T149.85 156.5 164.8 135.7500.8016:00:09.948 10

APPENDIX F - UPDATE FORM

TO: ACT-510 (Ext. 4480)

FROM: __________________________________ _________________
(Name) (Routing Symbol) (Ext.)

DATE: ____________________________

RE: TARGET GENERATION FACILITY TO FLIGHT SIMULATOR INTERFACE CONTROL DOCUMENT - MAY 15, 1995

Paragraph number, table number, figure number or appendix:

Page number:

Recommended change:

NOTE: If change is extensive, please attach revised pages, or additions. Make changes in ink and place a bar in the margin to flag the change.